Two years of a pluralistic work: ASN published a white paper on tritium.

M. Fournier[1], P. Jaunet[1]
[1]*Autorité de Sûreté Nucléaire, 6 place du Colonel Bourgoin, F-75572 Paris cedex 12 France*

Abstract. Radioactive releases in the environment around civilian nuclear facilities have significantly decreased over the last few decades, with the exception of tritium. In late 2007, papers published in the UK (RIFE 11 report, study by the HPA's Advisory Group on Ionising Radiation (AGIR)) raised questions as to the behaviour of tritium in the environment. Given this context, ASN wanted to get a clear analysis of the existing studies into the issue and in early 2008 decided to establish two independent pluralistic working groups. Two main points of the discussions are on the bioaccumulation and the biological effects.

1. THE CONTEXT

Radioactive releases in the environment around civilian nuclear facilities have significantly decreased over the last few decades, with the exception of tritium. Discharges of this element are forecast to increase due to expected changes in the fuel management methods used by the NPP, and also due to new tritium-emitting facilities, including new power plants that are to be built, and the ITER project. The overall impact of tritium releases in France is low, with an annual effective dose of roughly one µSv or less for the reference groups.

In late 2007, papers published in the UK (RIFE 11 report, HPA's Advisory Group on Ionising Radiation [1]) raised questions as to the behaviour of tritium in the environment, in particular focusing on potential accumulation in organisms of organically bound tritium (OBT) from tritium released into the environment and on methods for assessing the biological impact of tritium in humans.

ASN wanted to get a clear analysis of the existing studies into the issue and in early 2008 decided to establish two independent pluralistic working groups ("Tritium Impact" and "Tritium: Defence in Depth"), chaired by Dr Patrick Smeesters of the Belgian Federal Agency for Nuclear Control (AFCN) and Mr Roland Masse of the Académie des technologies.

2. THE GROUPS

From the very outset, the desire for a pluralistic approach was at the heart of the composition of these groups : experts from the CEA, CNRS, GSIEN, Institut Curie, IRSN, universities and European Commission "Article 31" experts [2]), representatives of operators (ANDRA, AREVA, CEA, EDF and ITER), associations (ANCCLI, ACRO and CLI) and safety authorities (ASN, DSND)). The

groups had to review current scientific knowledge about the environmental and health impact of tritium, the sources and impact of tritium and to issue recommendations, where necessary. All these bodies had the opportunity to express their opinions through a presentation and discussions and to issue a text which is reproduced in full in the white book [3]. The texts express the point of view of their authors only.

The specific brief the groups received was to explore the potential for tritium accumulation along the food chain and whether there is a need to reassess the health effects of beta radiation from tritium (“Impact” group), and the consequences of the future increase in tritium discharges, and industrial solutions for tritium separation and sequestration from liquid or gaseous discharges (“Defence in Depth” group).

The groups began their work in May 2008 and it was completed in April 2010. Each group met 5 or 6 times, and two joint meetings of both groups were needed to finalize the conclusions and recommendations. Both working groups have provided their conclusions and recommendations in June 2010.

The exchanges and discussions between representatives from different origins are not obvious a priori. Indeed, the success of this is only possible if some barriers are removed. First, the working groups had to clarify a number of concepts and define precisely the meaning of these concepts. This is particularly true of the notion of bioaccumulation, bioconcentration and bioamplification[1]. This semantic clarification work was not immediately identified by the working group. Through the presentations and exchanges, it appeared as an essential exercise to arrive at findings and interpretations shared by all members. The recommendations of the working groups also include for each term mentioned above precise definitions of these concepts.

Second, although members of the working groups were asked to participate in the groups according to their knowledge, work, experience, members were not quite without bias towards one other. Thus, some experts have sometimes questioned scientific legitimacy of association representatives. Conversely, some association members were able to question the impartiality and independence of expert analysis of nuclear operators. Nevertheless, the sagacity and sound quality of the chairmen and the strong involvement of the participants have created favorable conditions for the emergence of multiple points of view and for the work quality. An inventory of current knowledge had first been prepared. Discussions were then undertaken on the interpretation of existing data. On a number of issues, differences of opinion or interpretation have clearly emerged.

---

[1] The members of the group agreed on the following definitions :

Bioconcentration means the presence of substances in an organism (e.g. aquatic organism) at a higher or lower concentration than the concentration measured in its environment (e.g. water) at the same time. The bioconcentration factor is simply the ratio between contaminant concentration in the living organism (or one of its organs or tissues) and the concentration of the same substance in the organism’s environment. Bioconcentration factors may thus be greater than, equal to or less than 1.

Bioaccumulation : this term is often used with the same general meaning as bioconcentration. The French General commission for terminology and neologisms [4] describes bioaccumulation as a “process by which a pollutant present in a biotope penetrates or accumulates in some or all of a living organism and can become harmful; by extension, the result of this process.” In the strict sense of the word, bioaccumulation results from the gradual accumulation of a contaminant or toxic substance in an organism, from diverse sources, including the atmosphere, water and food, until an equilibrium is reached between accumulation and excretion of the substance [8], with a concentration in the organism that is greater than that in the contamination sources.

Bioamplification : if this phenomenon is reproduced at each trophic level (with a cumulative increase in concentration of the substance as it moves up the food chain), the term used is bioamplification.

Two examples from the conclusions and recommendations of the working groups illustrate the interest of pluralistic exchange. The first example concerns the question of the accumulation of tritium along the food chain and the second has to do with the evaluation of the biological effects of tritium and the consequences on the assessment of effective doses.

3. THE MAIN POINTS OF DISCUSSIONS

3.1 The potential for tritium accumulation along the food chain

The presentations of the members of the group focused on observations carried out in marine environments: Cardiff Bay, Sellafield and La Hague. Less data were discussed for the terrestrial environment.

In the case of the plant producing labelled molecules in Cardiff, the group agrees to a case of tritium bioconcentration. The hypothesis concerning bioaccumulation/bioamplification applies if the tritium comes from tritiated organic molecules.

For the Sellafield site (fuel reprocessing facility managed by BNGSL which discharges tritiated water), the tritium content found as free tritium (HTO) or organically bound tritium (OBT) in marine fauna (fish, crustaceans and molluscs) varies by a factor of 10 with respect to the concentrations found as HTO in the sea water with 1 to 2 years hysteresis (time lag) between the maximum discharge values and the maximum tritium values in molluscs and flat fish.

These observations were interpreted in different ways by various members of the group. Some consider that the abnormally high concentrations measured in fish near Sellafield may result either from remanence in sediment labelling following previously large discharges or from the existence of tritiated organic molecules in the same water outflow. Others consider that this is a case of bioaccumulation which is related to the discharge of tritiated water. According to proponents of this view, the hypothesis of marine currents carrying tritium-labelled organic molecules discharged by the Cardiff radiochemical plant is refuted by the Association for the control of radioactivity in the West (ACRO) [5]. The argument is that the analysis carried out near the Wylfa nuclear power plant (NPP), on the west coast of the UK between Cardiff and Sellafield, did not find any detectable presence of tritium in the marine fauna. Other members of the group felt they did not have enough information to form a view.

For the La Hague site (fuel reprocessing facility run by AREVA NC, discharging tritiated water), the IRSN [6] concludes that the research into tritium in the environment (joint IRSN-AREVA campaigns) do not show any tritium bioaccumulation/bioconcentration.

ACRO points to the very limited number of measurements taken around La Hague between 2000 and 2009 on edible marine produce (flat fish, crustaceans, molluscs etc.). ACRO highlights the fact that measurements performed on marine organisms in Cardiff Bay suggest that algae are a poor indicator for monitoring tritium contamination in marine fauna, since tritium concentrations were significantly higher (by a factor of over 10) in fish than in algae. ACRO considers that the choice made to take measurements in algae for monitoring purposes is not the most appropriate method for identifying concentration phenomena in marine organisms. Finally, ACRO reports that bioconcentration (by a factor between 2 and 7) was found in an older study (from the period 1981-1985) in a small number of available mollusc, crustacean and fish samples.

With regard to the terrestrial environment, CEA [7] reported the results of monitoring measurements performed at the Valduc site by CEA itself and, in parallel but independently, by a local association (SEIVA). The levels of radioactivity in water produced in combustion of OBT (dry organic plant matter) were found to be between the activity in airborne water vapour and the activity in groundwater. In the CEA's view, these results do not reveal any phenomenon of concentration in the organic matter. According to CEA, the IAEA calculations could be excessively conservative, by overestimating the free water concentration in plants.

Some old publications on environmental data (from the 1970s and 1980s) suggest that tritium could bioamplify in some aquatic trophic chains and that the nutritional pathway is predominant with respect to the direct pathway (water).

IRSN summary report [8] states that "on the basis of currently available knowledge and with "normal" environmental activities, no phenomenon has been identified as liable to cause significant "bioaccumulation" over the long term and no measurement has pointed to this." The same report does however mention that "for animal organisms, there is little data with respect to the complexity of the issue (number of processes involved, interactions and variability according to species, age and diet)".

The group wishes to highlight the still fragmentary nature of current knowledge on remanence and on tritium behaviour in sediment, and the need to use targeted multidisciplinary studies with rigorous protocols to provide experimental verification of the hypotheses put forward in older studies, in particular regarding the possible influence of the activity of microorganisms in aquatic sediments when organic tritium is remobilised in aquatic animal organisms. In general, the scientific data regarding the conversion of tritiated water into organic tritium along the food chain should be enhanced. Reliable quantitative estimates are required. The group considers that the only way to clear up doubts, assess the effect of the various factors at stake, in particular regarding the distribution of tritium in the different compartments (including organic matter in sediment) and to better define the free and organically-bound tritium components in living species is to use appropriate environmental measurement campaigns, with a scientific approach. In the marine environment, these campaigns must focus on a large enough number of edible marine produce samples from various trophic levels (flat fish, crustaceans, molluscs etc.).

There is another open question – are there sources of tritium releases in organic form other than those from industries that synthetically create labelled molecules? The aforementioned IRSN report highlights the gaps that exist in knowledge regarding the presence of labelled molecules with high levels of specific activity, their behaviour and the consequences in terms of tritium accumulation. The IRSN feels that a key priority is to carry out metrology studies into the various physicochemical forms (speciation) in which organic tritium is liable to affect humans.

3.2 Appreciation of the biological effects: *RBE and w_R*

For reference, the radiation weighting factor (w_R) is used in health physics to take into account the effect of radiation type in inducing long-term stochastic effects such as cancer or hereditary effects. Opinions were hotly divided within the group with regard to the need to increase the value for tritium (currently w_R=1).

In opposition to the findings of the reports [1] [2], the ICRP recently confirmed its choice of a w_R of 1 for tritium and low-energy beta emitters, taking into account on the one hand the uncertainties around the issue and on the other hand, purely forward-looking objectives for the radiation protection system and the priority to be placed on optimisation and dose constraints. The IRSN is of the opinion that the RBE of tritium for stochastic effects, on which the weighting factor w_R is based, is closer to 2 than 1, but considers that choosing a weighting factor w_R of 2 rather than 1 would only have a minor significance in routine situations and should only be used in assessing individual risks. This opinion is not shared by the associations, which are arguing for a weighting factor of 5 for the sake of precaution. A w_R of 2 should be used in individual risk assessment situations. No consensus was reached within the group as to the factor to be used in routine situations, but the need to comfort a value is real, “with stronger arguments than those used by ICRP until now”, as expressed by some experts and all the public stakeholders.

4 POINTS OF AGREEMENT

If differences of opinion have arisen, the work of working groups has been highlighting a number of points of agreement. For instance, the groups highlight the small impact that tritium releases have in France. They also showed that detritiation in PWR reactors in NPPs and in the La Hague is not currently achievable with the best technologies currently available at an acceptable cost.

Most importantly, the members points out that current knowledge about the biological effects of tritium is in some areas rather fragmentary. In order to answer the questions, the following topics should be investigated further by research bodies:

- harmonisation of dose assessment methods according to the physicochemical form of the tritium, contamination pathway and length of exposure;
- studies into the effects of tritium exposure on embryos and foetuses;
- investigation of new approaches to the potential induction of hereditary effects.

In most cases, this research will require international cooperation.

5 THE WHITE PAPER AND ASN POSITION

ASN has published in July 2010 the White Paper tritium. It is entirely available on a dedicated website (http://livre-blanc-tritium.asn.fr) in French and partly in English. It includes the summary of the work and the recommendations drawn up by the working groups, the contributions written by the group members (these articles express the point of view of their authors only), the ASN position statement and its action plan, drawn up on the basis of the recommendations made by the two working groups, with four directions of development.

ASN considers that the development of measurement protocol for the measurement of organically bound tritium must be a priority and has solicited the standardization organization in order to publish shared and recognised methods. In the ASN’s view, this work must lead to the production of a normative guide. It is a vital first step prior to launching further studies.

For the control of discharges**,** ASN, as part of the development of defence in depth, considers that publishing the quantities discharged for each facility on an annual basis will ensure a long-term, reliable inventory of sources of tritium production. The public should be regularly and specifically informed of this inventory of tritium discharges by nuclear operators. Accounting for discharges from all facilities should continue to be managed in all circumstances, as is the case today. A “technology watch” should be set up with respect to detritiation technologies.

ASN estimates that tritium monitoring in the environment and throughout the food chain must be supplemented. Measurements performed must take into account the physicochemical forms present. The ASN will consequently ask operators to characterise the physicochemical forms of tritium in the discharges, particularly with regard to any possible organic precursors (small tritiated organic molecules). Sampling plans in the different compartments of the environment must be undisputed and shared. In particular, the choice of animal and plant species to be measured must be reviewed in order to remove any species bias.

The ASN will ask the ICRP to review the value of the tritium weighting factor (w_R) used in calculating effective doses. Even before the ICRP’s response is known, the ASN ask operators to supplement the radiological impact studies for their projects with a critical study in which a variant using a tritium weighting factor (w_R) of two is included.

6. CONCLUSION

The ASN is pleased with the high quality of the work and the large bibliography provided, which have led to the recommendations issued at the end of each group’s summary. The studies highlight the small impact that tritium releases have in France. However, they do also show the need to carry out further study and research in order to supplement current data and knowledge on the behaviour of tritium in the environment. Clearly, the one key word that comes up repeatedly is (further) “research”.

The ASN has drawn up its action plan on the basis of the recommendations made by the two working groups. It also hopes that research bodies take into account the requests made by the working groups, as described in the summary of work and recommendations [3].

Finally, the ASN believes that all stakeholders must continue to think about and discuss these issues and to this end suggests the establishment of a supervisory committee to oversee the actions undertaken following the recommendations of the working groups.

Acknowledgments

The authors are grateful to the members of the 2008-2010 tritium groups.

References

[1] Health Protection Agency, Review of Risks from Tritium, Report of the Independent Advisory Group on Ionizing Radiation, November 2007
[2] European Commission, EU Scientific Seminar 2007 “Emerging Issues on Tritium and Low Energy Beta Emitters, Radiation Protection No 152, Luxembourg, 2008 1/8
[3] http://livre-blanc-tritium.asn.fr/
[4] Journal Officiel de la République française, Avis et Communications, 4 February 2010
[5] ACRO http://livre-blanc-tritium.asn.fr/etat-des-connaissances/ch4-2-rejets-marins-du-tritium.html
[6] IRSN http://livre-blanc-tritium.asn.fr/etat-des-connaissances/ch1-2-tritium-dans-l-environement.html
[7] CEA http://livre-blanc-tritium.asn.fr/etat-des-connaissances/ch4-6-connaissance-des-transferts-eau-tritiee-atmospherique.html
[8] IRSN, “Le tritium dans l’environnement”, Report DEI 2009-05